NEW DEVELOPMENTS IN FOREST FIRE FIGHTING EQUIPMENT

By

Ira C. Funk
Chief, Fire Equipment And Aeronautics
Forest Service
U. S. Department of Agriculture

The demand of a rapidly growing population in the United States for timber, forage, water, recreation, and other resources of forested land is causing a constantly increasing pressure to reduce forest fire losses. As part of a program aimed at reducing these losses, Federal, State, and County forest protection organizations and equipment manufacturers have been working together to develop adapt, standardize, and improve the reliability of forest fire fighting equipment.

The Forest Service's fire equipment program, nationwide in character, is extensive. Many projects are conducted in cooperation with other Federal and State forestry agencies. Thirty-five fire equipment development and testing projects were coordinated nationally during this past year. Most of these projects and programs are planned and coordinated through a system of boards and committees. A few States have well-equipped facilities for fire equipment development and testing, and conduct equipment programs to meet their special needs. The equipment industry has assisted in many of these programs primarily by perfecting certain items, by introducing better materials, by improving manufacturing methods, and through quality control.

Recent work includes much of interest to Agricultural Engineers. Among the large variety of items are:

1. Self-propelled, gasoline-powered, fireline, scraping and trenching machine--similar to garden-type tractor, but more powerful and with gradability of 45 percent.

2. Gasoline engine-powered duffel carrier for transporting up to 400 pounds of equipment over narrow mountain trails and cross country.

3. Gasoline engine-powered, hand-held, brush cutting tools.

4. Pumper-tanker fire apparatus for various sized vehicles.

5. Improved tractor-drawn fireline plows.

6. Improved bulldozer with digger teeth and better control features.

7. Improved guidable parachutes for smokejumpers.

8. Improved parachute harness for smokejumpers.

9. Parachute landing simulator for smokejumper training.

10. Improved equipment and methods for parachuting equipment and supplies.

11. Apparatus and procedure for accelerated testing of fire pumpers.

12. Apparatus and procedure for determining abrasive resistance of fire hose.

13. Apparatus and procedure for testing spark arresters for internal combustion engines.

14. Equipment for mixing and handling fire retardants such as sodium calcium borate slurry in large quantities.

15. Tanks, discharge system, and controls for "cascading" liquid fire retardants from Grumman Avenger Torpedo bombers and helicopters.

16. Fire hose dispensing tray for helicopters.

17. Collapsible external tanks for transporting fire chemical retardants or water via helicopter.

18. Pumper and hose outfit for helicopter transport.

19. Improved instruments for measuring and recording weather and other conditions affecting fire danger.

Details concerning only a few of these items can be given here, since a separate paper would be required to treat each one fully. Illustrations may be found in a separate section immediately following the text.

Fireline Trenchers

Early gasoline-powered fireline trenchers were manually propelled and used the rotating flail to scrape the vegetation, leaves, and duff from the ground. Although the machines did a good job in making a narrow fireline, they were considered "man killers" by their operators. On steep slopes several men were required to pull the trencher around a fire. Recent objectives have been to develop self-propelled machines that will clean an 18- to 36-inch wide line to mineral soil at 1/2 to 2 miles per hour and climb a slope of 45 percent.

Tests of several specially designed self-propelled models, similar to two-wheeled garden tractors, brought out several design problems and established the limitations of the two-wheel side-by-side configuration. These problems included loss of traction in loose material when attempting to start or to accelerate up a steep slope, severe downthrust on control handle bar when climbing a steep slope and upthrust on handle bars when descending a steep slope. Various designs of metal wheels and tire treads were tried in order to improve traction.

Special power transmission systems were designed to permit power to be applied smoothly and slowly. One system employed a hydraulic pump and hydraulic motors. In another interesting model, a planetary transmission in combination with variable speed V-belt sheaves were used. A special feature of this model was its simplicity of control. One small lever on the handlebar could control speed, gear change, clutch action, and direction of travel through power steering. We really thought we had something until a maximum drawbar pull test was made. Unfortunately, the V-belts and self-adjusting sheaves wouldn't carry the torque load indicated by manufacturers' ratings, and adequate power could not be transmitted to the wheels.

Recent successes have been obtained with a single-track crawler machine and machines with two low-pressure tired wheels in tandem. These arrangements have a good potential in solving the handlebar thrust and the traction problems.

Trenching or digging mechanisms used on these small tractors are a result of many years of development. Three basic designs have proved to be satisfactory under different combinations of operating conditions. The flail or rotary beater serves best where there is much heavy or firmly imbedded rock. Where surface rock, six inches in diameter or less, is loose or not too firmly imbedded in hard, baked clay soil, the spiral auger or a rotating serrated disc scalper works well. Both of the latter types are mounted on the front of the machine. The flail may be mounted on the front of the machine, but has been generally mounted on the rear.

By combining the good features of these several machines in one or two models, we hope to have a usable light powered trencher for fireline construction work by the end of the year.

Fireline Plows and Truck Transport

Horse-drawn plows of many descriptions were used in the early days to construct firelines. Today, hundreds of tractor-drawn plows, specially designed for fire work, are in use. Early development of special plows for fire fighting apparently started in the Pacific Northwest. However, plows soon lost out in competition with bulldozers in steep, rocky and heavily timbered areas. In Michigan and other Great Lakes States, and in the Southeastern States, plow development has been under way for many years. Recently, fireline plows have found favor on the national forests in New Mexico and Arizona and are regaining favor on some national forests of the Pacific Northwest.

All fireline plows are essentially of the double bottom or middle buster type. Some have fixed-coulters to split the sod or slice through vegetation. Others have rolling coulters to split the sod and vegetation and to lift the plowpoint over large roots or rocks. Fixed moldboards are used on some plows to increase the width of the furrows. Most popular models, where little or no rock is present, have discs on each

side to extend the width of the furrows. Some plows are mounted directly on the tractor and have hydraulic or cable winch lift. Most popular, however, are those with wheels or "sulky carriage" for cross-country travel and depth gaging. In rocky and steep-sloped mountain areas, the chisel-pointed middle buster is a favorite.

In order to determine performance and evaluate design features of the large variety of plows used in the Southeast, the Forest Service, in cooperation with several State Forestry agencies, conducted performance tests of different designs and sizes of plows. Michigan State and others have conducted similar tests. Great care was taken in classifying soils, vegetative cover, and other conditions affecting the performance. Tests were generally limited to the range of conditions for which the tractor-plow combination was designed. Information obtained on these tests resulted in several improvements in plows and now serves as an aid in selection of tractor-plow equipment over a wide area.

The most recent developments in fireline plows include a redesign of the Forest Service's "Talladega Plow" for rocky mountainous areas and the transport trucks for a 25 drawbar horsepower crawler tractor and plow. This work was done at Albuquerque, N. Mex. Improvements to the plow include a new combination hitch and drawbar with hydraulic lift and down pressure to replace the cablewinch, and adjustable and replaceable plow point and replaceable bottoms.

A newly developed transport truck bed for a 2-1/2-ton truck has hydraulic tilt equipment and telescopic steel ramps built into the bed. With this equipment the truck has multiple use as fast transport for tractor plow, dump truck, or stakeside.

Spark Arrester Performance Tests

Even in this day of high technical advances we are suffering from fire losses caused by sparks from motorized equipment. A recent fire near Santa Barbara, Calif., which burned 9,560 acres of high-value watershed lands and cost $186,000 to control, was started by an agricultural tractor with an inadequate spark arrester. Many regulations and laws require that "adequate" or "approved" spark arresters be installed on internal combustion, engine-driven equipment operating in hay fields and forest areas. However, to enforce these laws someone must determine what is "adequate" spark-arresting performance and which arresters shall be approved.

Based primarily upon the work of J. P. Fairbank and Roy Bainer, the Spark and Flame Arrester Committee of the Society of Automotive Engineers developed a specification for spark arresters including performance requirements, test procedures, and apparatus. This specification was adopted by the SAE in 1951. Soon these test procedures were believed impractical in that an arrester would have to be tested on each make and model of engine for which its use was intended. Therefore, in 1952, the Forest Service contracted with the University of California

at Los Angeles for initial work in developing a simplified testing procedure and apparatus. The simplified apparatus employed a constant velocity discharge of a centrifugal blower at room temperature in place of the hot, pulsating discharge from an engine. For certain arrester designs, good correlation was obtained between tests on engines and tests on the constant velocity apparatus. Correlation was poor and unreliable, however, for some designs.

About three years ago, the University of California apparatus was reconstructed and improved at the Arcadia Equipment Development Center. Since thenattempts have been made to introduce a pulse in the flow of air from the blower to represent actual engine discharge flow and pressure patterns. These attempts have been unsuccessful.

Most recent studies at Arcadia, involving an aerodynamic approach in determining the drag on carbon particles by engine exhaust gases and by cool airstream, indicate that it may be necessary to use hot gases with pressure pulses as from an engine for a fully reliable test. Further work is now being conducted on this. In the meantime, however, we are planning to use test results with the blower apparatus supplemented by some engine tests. Test data now available indicates that it may be necessary to accept arresters having a spark-arresting efficiency of 80 percent for small size carbon instead of the 90 percent recommended by earlier investigators. This would, of course, be subject to change as improvements are made either in testing methods or in arresters.

Airplane Tankers

The idea of fighting fire by dropping water or fire-extinguishing chemicals on them from fixed-wing aircraft was given serious thought in the early 1920's. In 1936, extensive aerial bombing experiments were conducted by the U. S. Forest Service and again in 1946 and 1947. Although results of experiments conducted in 1947 looked promising, they were never carried to trial application. In the meantime, Canadians developed and put into practice a bombing technique employing specially constructed paper bags.

In 1954, a review of all previous work was made by cooperating Federal, State, and private organizations under a cooperative program called "FIRESTOP." This group soon discarded the bombing idea as too dangerous to persons on the ground. It could not be successfully used in close support of fire fighters.

Little had been done in trying bulk dropping or cascading uncontained water. In 1953, a Douglas Aircraft Corporation employee making performance tests of the DC-7 noted that a material amount of water reached the ground at a cruising speed of 200 miles per hour and at a slow--flight speed of 100 miles per hour when water tanks used as ballast were emptied in low level flight. Following these observations, brief experiments were made with this equipment at Rosamond Dry Lake, Calif. When 375 to over 500 gallons of water were discharged through 6-inch

gates at 150 to 600 feet altitude, water reached the ground in appreciable amounts.

A Grumman Avenger single-engine torpedo bomber (Navy TBF or TBM) was selected and equipped with a temporary 600-gallon, 2-compartment tank in its bomb bay for further experiments. This plane has a disposable load of about 5,000 pounds. It is designed for carrier and short field landings and low level operation. It has the essential maneuverability for the mountain operations contemplated. Five test drops made under FIRESTOP showed great promise. No serious airplane control difficulties were encountered when the water was discharged. An area 90 feet wide by 270 feet long was "drenched" by a tankful when cascaded from an altitude of 50 feet. At 100 feet, wind drift can critically affect the dispersion pattern. Operation FIRESTOP terminated before these experiments could be carried to definite conclusions. Ground experiments with water and chemicals showed that at least 4 gallons of water or chemical solution per 100 square feet were required to adequately cover brush and grass. Strips up to 50 feet wide would be necessary under severe burning conditions.

In 1956, a squadron of 7 privately owned and operated agricultural spray planes (Stearmans and N3N's) equipped with 100 to 150 gallon tanks and extra large, specially designed discharge gates were used experimentally on 23 fires in California. These air tankers dropped 83,000 gallons of water on 21 of the 23 fires and about 40,000 gallons of sodium calcium borate slurry on 12 of them. This air support was credited as a deciding factor in assuring control on 14 of the 23 fires. Although limited in load capacity and lacking radio for directing purposes, these planes did a good job.

Late in 1956, attention was again given the Navy torpedo bombers. Eight Grumman Avengers (TBM's), which were obsolete for Naval use, were transferred to the Forest Service. During the past few months several tank configurations have been under development for the TBM. One having two compartments side by side, running nearly the full length of the bomb bay has discharge gates covering the entire bottom of each compartment. This design permits instantaneous release of the entire 200-gallon contents of each compartment, individually or simultaneously. Simplicity and safety were primary considerations.

The center of gravity of the tankloads are located so that no appreciable effect is noticed on the controls when compartments are discharged individually or together. Because of the arrangement, no special sequence is required in discharging compartments of tank. The capacity of the tank is conservative in order to limit loading to safe quantities for low-level flying over rough mountainous terrain with turbulent air and at high altitudes. A difficult design problem for tanks of this type is to eliminate leakage from the long and narrow discharge gates required for cascading fire retardants. This has been accomplished with reasonable success.

Another tank design has four tanks with compartments in tandem. Discharge controls automatically give a sequence for discharging compartments that will retain center of gravity of load within safe limits.

Since the tank with four tandem compartments eliminates long, narrow discharge gates, the problem of leakage is reduced. However, discharge controls and piloting become more complicated. From the fire fighters' viewpoint, the ideal aerial tankers for fast initial attack should have a minimum four 100-gallon-capacity tank compartments. This would enable one plane to surround a small fire with fire retardant in three to four passes without returning to its base for reloading.

Helicopter Fire Apparatus

Small helicopters such as the Bell 47's and Hiller 360's have been used since 1947 in scouting forest fires and in speeding up delivery of men and equipment to strategic places on the fire front. During 1956, helicopters flew more than 1,900 hours in forest fire work--mostly in national forests of California.

On Operation FIRESTOP in 1954, an all-out effort was made to explore the potentials of helicopters in fire fighting. Although accessories were of expedient construction, the ability of the helicopter to pull out hose from a fire truck, drag it over impenetrable brush and direct the play of water on a fire was demonstrated. It was also shown that small helicopters could lay hose from a dispensing tray and that large helicopters could deliver pumper outfits with hose and water tanks to strategic places on the fireline. However, much work in perfecting the equipment was yet to be accomplished.

On March 14, 1956, the Forest Service entered into a cooperative program of helicopter use development with the Corps of Engineers, U. S. Army, Engineer Research and Development Laboratories, Ft. Belvoir, Va., and the State Division of Forestry of California. This three-year program is designed to develop use of the helicopter as a supporting facility in fire fighting operations particularly where accessibility by ground equipment is either impossible, impracticable, or too slow to be effective. The accessories being developed under this program are:

1. Hose-laying apparatus accessories designed to lay fire hose on the ground or over brush and then from a helicopter in flight.

2. Helitanker. An external tank carried below a helicopter fuselage from which water or chemicals can be dropped directly on the fire.

3. Helipumper. An airborne fire apparatus, including tank, pump, and hose.

    a. External type. A unit to be carried outside the fuselage which is designed for quick attachment or detachment from the helicopter and can be easily transported to critical sectors of a fire.

    b. Internal type. A unit to be carried inside the fuselage designed as a kit for easy installation and removal in standard

helicopters and which can be used to fight fire while the ship is hovering.

Progress to date indicates that our schedule will be accomplished on time. The Forest Service has completed the development and testing of a fire hose dispensing tray for the small helicopter. This tray handles 1,000 feet of 1-1/2-inch dacron jacket, rubber-lined hose, or 1,500 feet of Forest Service specification, lightweight, 1-1/2-inch, unlined, linen hose. Several of these trays will be in actual fire service this summer.

The work accomplished by the Army in this field is a subject of another paper on this program.

External helitanks in two sizes, 25- and 40-gallon capacity, have been developed for the small helicopter. Tanks of 300-gallon capacity are planned for the Army's H-21 helicopter.

In order to obtain further information on most of the items listed in this paper, the reader should refer to the list of references which follow the illustrations.

A full review of fire equipment development work shows that much has been accomplished in the past few years. Important improvements in reliability and performance are making our equipment dollars go farther. We are beginning to see the development of practical possibilities of air attack and air support to the ground fire fighters. But in view of known operational limits of aircraft under conditions of high turbulence and low visibility, we realize we must continue to search and perhaps to think unorthodoxically if we are going to make appreciable headway in saving valuable resources at a reasonable cost.

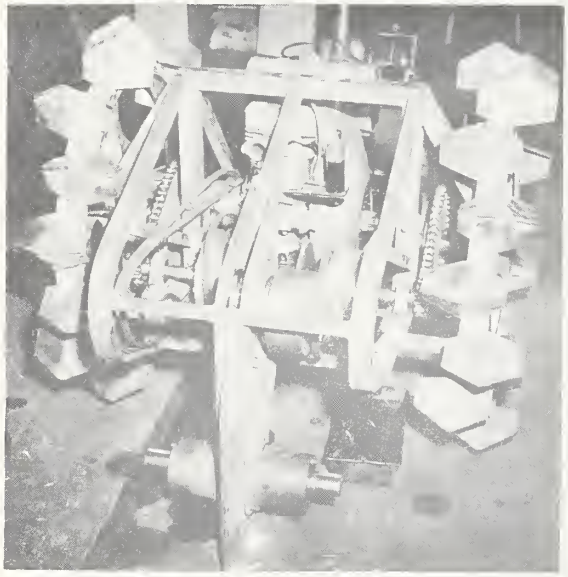
Our equipment development engineers are being encouraged to keep up on new developments in such things as electronics, guided missiles, rockets, turbojets, and other items that may some day assist us in overcoming present obstacles to successful protection of forest resources.

ILLUSTRATIONS

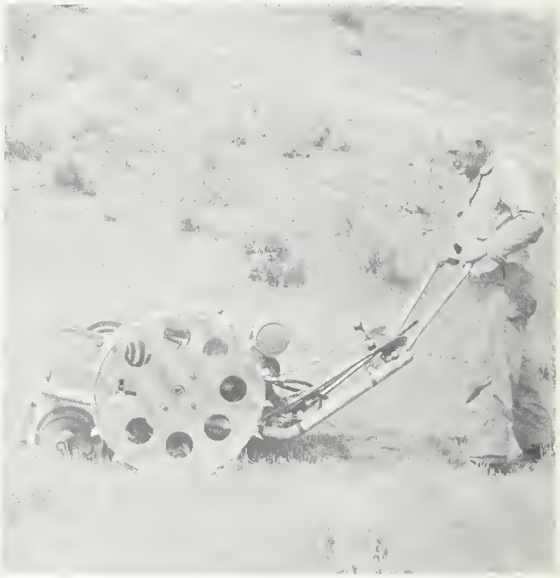
Fire equipment played an important role in controlling the 41,000-acre McKnight fire on Gila National Forest in New Mexico.

FIRELINE TRENCHERS

Flail-type trencher developed by Northern Region, U. S. Forest Service. Weighs only 265 lbs., has side-hill leveling feature. High tensile strength chain flails with or without digger hammers on end proved most satisfactory for general service, including rocky ground.

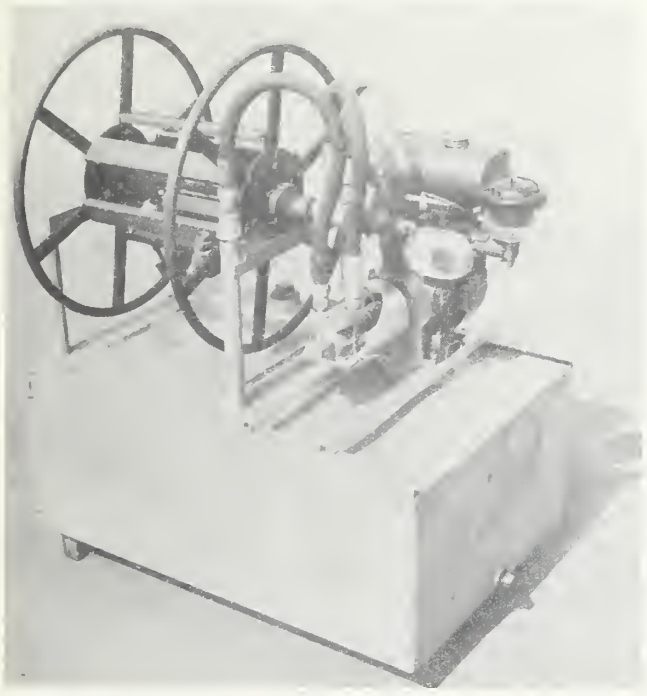


Spiral trencher (less spirals) with two-wheel tractor with planetary transmission; under construction.

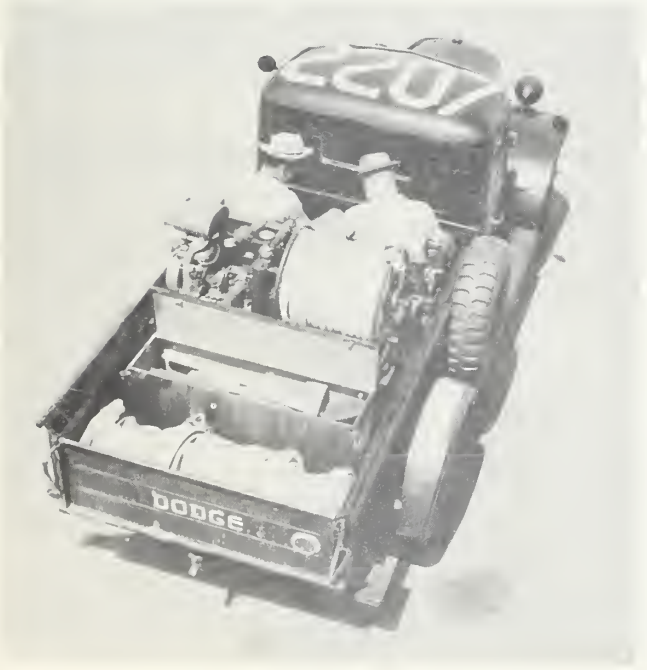


Spiral trencher mounted on special two-wheel tractor with hydraulic power transmission.

FOREST SERVICE STANDARD SLIP-ON PUMPER TANKER FIRE APPARATUS

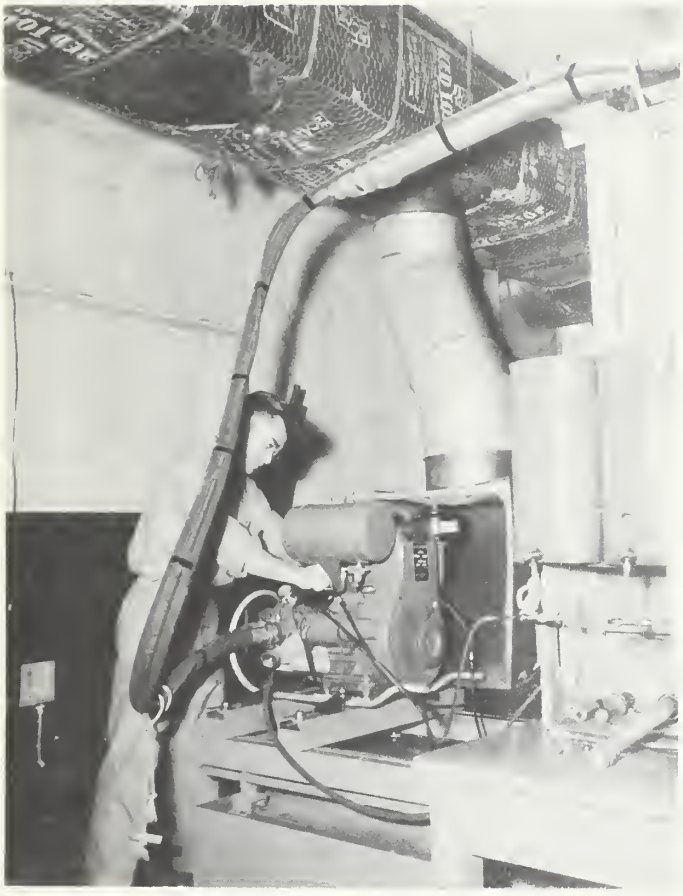


50-gal. Patrol Unit has 7-1/2-gal., 150-p.s.i. pumper; live reel--250-foot 1-inch hose capacity.

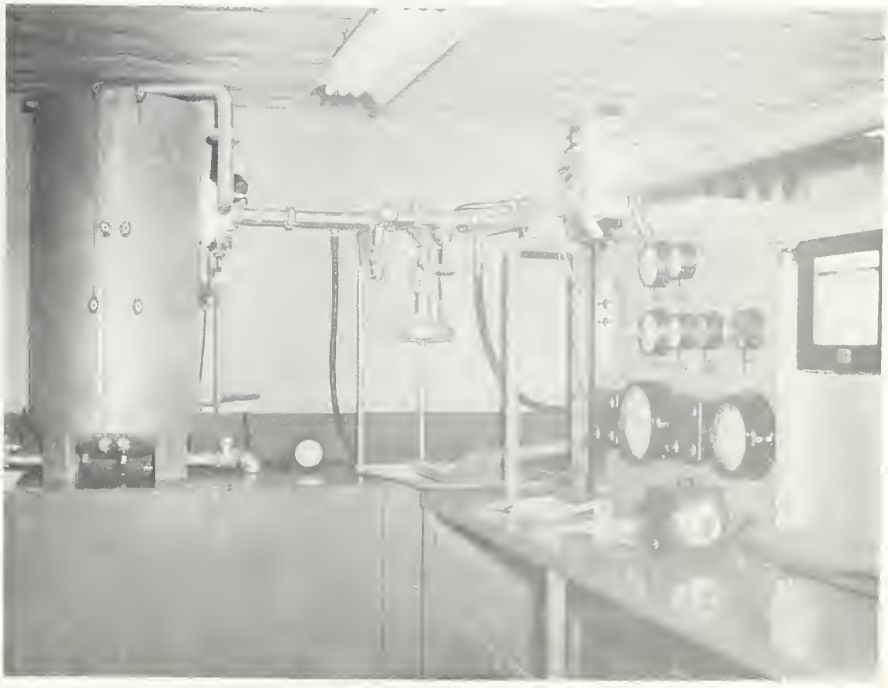


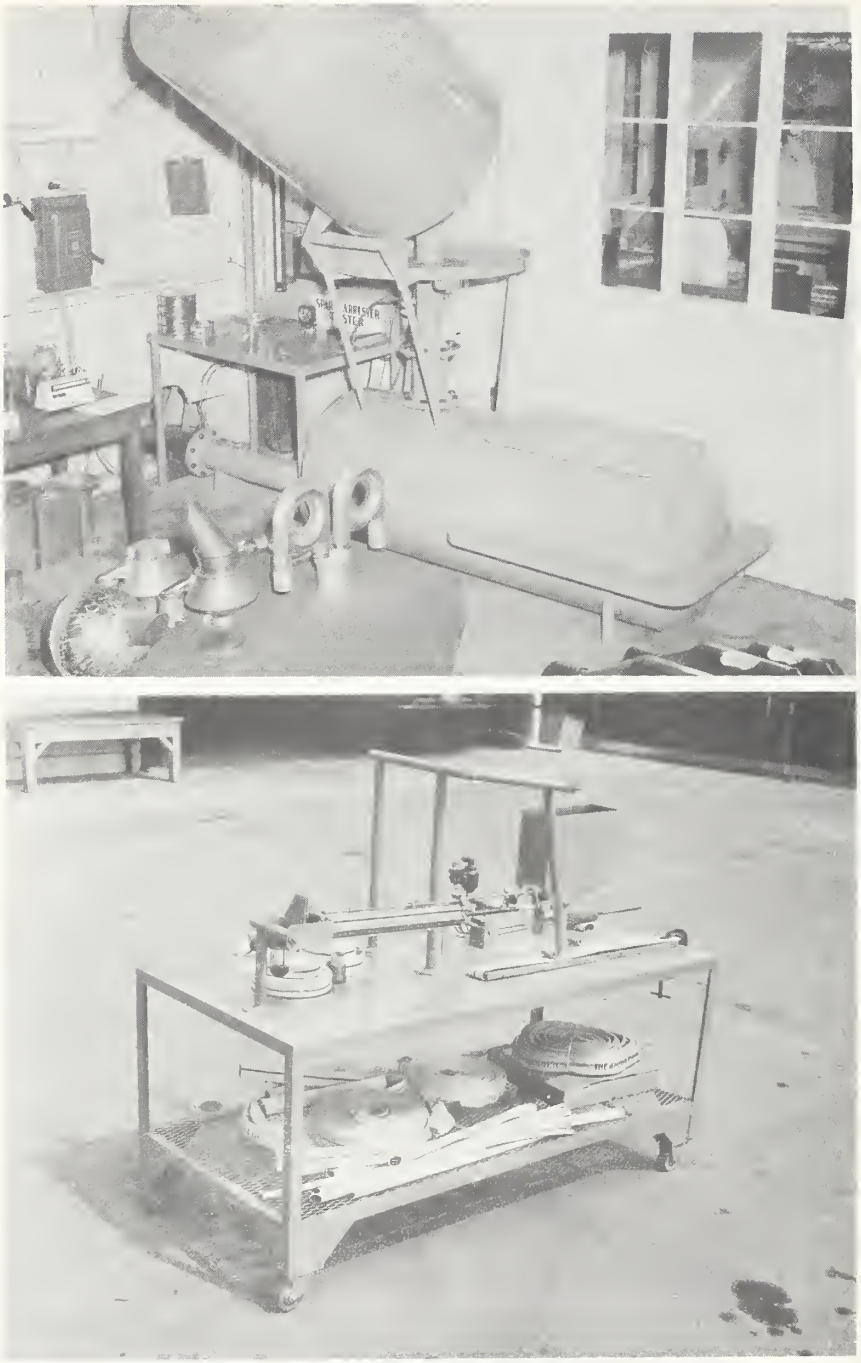
1/2- to 1-ton Unit with auxiliary combination seat and toolbox. Tank holds 60 to 200 gals., depending on number of compartments used for water. Reel holds 250 feet 1-inch CJRL fire hose. Pumper--17 gals. per minute at 250 p.s.i.

Improved Forest Service "Talladega" middlebuster with hydraulic lift, downpressure and replaceable chisel point and bottoms.



Fire Pumper Testing Laboratory, Arcadia Equipment Development Center, Forest Service, U. S. Department of Agriculture.



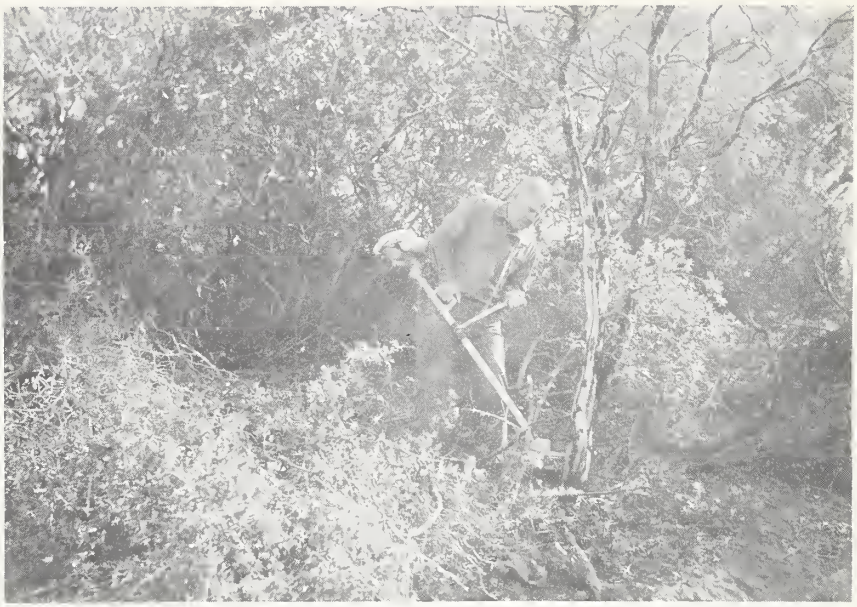


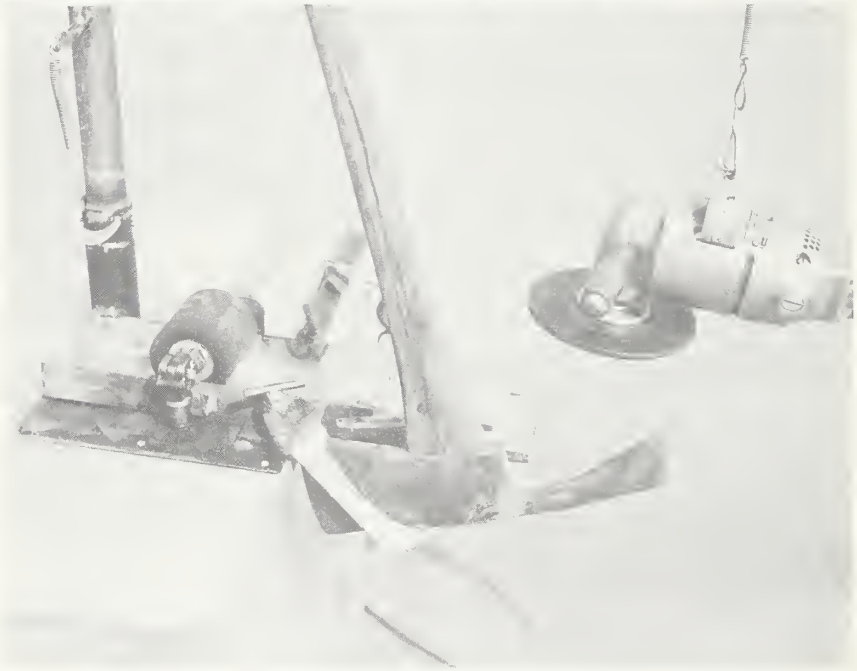
Top. Spark arrester testing apparatus, Arcadia Equipment Development Center, Forest Service, U. S. Department of Agriculture.

Bottom. Experimental apparatus for abrasion resistance testing of fire hose.

Top. Agricultural airplane cascading borate fire retardant on Inaja Fire, Cleveland National Forest, California, November 27, 1956.

Bottom. Borate line layed by plane helped to stop Inaja fire in critical place.





Top. Performance and service-life testing. Hand-held, gasoline-powered, brush-cutting tools. Angeles National Forest, California.

Bottom. Tool-sharpening outfit. Invented by Forest Service warehouseman and improved by Arcadia Development Center in cooperation with equipment manufacturers. Jig will hold any manual tool used in forest fire fighting. Cost of sharpening reduced 35%. Burning of sharpened edge eliminated.

Fire hose dispensing tray for helicopters. Lays 1,000 to 1,500 feet load of 1-1/2-inch fire hose in less than 2 minutes.

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